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JOHN F. KENNEDY SPACE CENTER

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GENERAL CRITERIA FOR DESIGN OF NEW EQUIPMENT AND FACILITIES TO BE UTILIZED AT KSC

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SECTION I
INTRODUCTION

1.1 PURPOSE

This document provides a brief summation of general requirements, for use by designers, for new equipment and facilities to be used at the John F. Kennedy Space Center (KSC). It is intended to ensure that at the beginning of a design endeavor the designers recognize and take into account the wide variety of factors that must be considered, along with specific design specification items. These general requirements were developed from past experience in the space program, and are meant to improve equipment and facilities in a manner that will enable the operators and maintenance personnel to perform more efficiently.

1.2 SCOPE

The general requirements listed herein supplement rather than replace existing specifications. Emphasis is placed on ensuring that designers consider a wide spectrum of factors before making a final commitment. Simplicity of operation and maintenance, cost effectiveness, and good design are best achieved prior to design reviews and manufacture. This will ensure that the product will be useful, operable, and maintainable at a reasonable cost. Consequently, utilization of these guidelines should precede the start of design endeavor.

References are made in Section II to material that describes these requirements in more detail and will enable designers to further study any item presented herein. The information is presented in the following manner:

Section I	Introduction
Section II	Applicable Documents
Section III	Requirements
Section IV	Quality Assurance
Appendix	Problem Areas at KSC

1.3 APPLICABILITY

The requirements listed herein apply to all Government or contractor designers of equipment, systems, and facilities to be located/used at KSC. Application of these requirements and existing specifications, along with proper liaison and coordination with associated operation/maintenance engineers during the early design phase, is paramount in meeting mission requirements. In the event of conflict between the requirements listed herein and approved specifications and/or criteria for a specified project or program, the latter shall take precedence.

1.4 APPENDIX

The appendix contains a compilation of some problems that have complicated the operation and maintenance activities at KSC. It is included for additional reference and utilization by designers.

SECTION II
APPLICABLE DOCUMENTS

2.1 GENERAL

This section contains a listing of applicable documents that provide additional information on the general requirements set forth herein and will enable the user to broaden his knowledge in a particular area.

2.2 NASA DOCUMENTS

The following NASA documents contain additional information on a specific subject and are applicable to all NASA facilities.

NHB 1700	NASA Handbook (Safety)
NHB 1700.1, Vol. I	Basic Safety Requirements
NHB 5300.4(IB)	Quality Program Provisions for Space Systems Contractors
NHB 5320.3	Electromagnetic Compatibility Principles and Practices
NHB 7320.1	Facilities Engineering Handbook
NHB 7500.1	Apollo Logistics Requirements Plan
NHB 7500.2	Apollo Operational Maintenance Plan
NHB 8080.1	Apollo Test Requirements
NMI 1052.31	DOD/NASA Agreement - AFETR and MILA
NMI 1052.49	MILA/CKAFS Common Item Supply Support
NMI 1052.79	NASA/USAF Agreement on Propellant and Pressurant Support
NMI 1142.2	Functions and Authority - KSC, NASA
NMI 6030.1	Transportation of Large Vehicles and Spacecraft
NMI 6410.1	Packaging, Preservation and Marking Requirements for Aeronautical and Space End Items, Components, Parts, and Associated Equipment

NPC 200-3	Inspection System Provisions for Suppliers of Space Materials, Parts, Components, and Services
NPC 250-1	Reliability Program Provisions for Space System Contractors
NPC 325-1	Design Criteria and Construction Standards
OMSF Dir No. 1	System Safety Requirements for Manned Space Flight
OMSF SPD No. 1	Office of Manned Space Flight, Safety Program
OMSF SPD No. 3	Safety Guidelines for Man-Rating Altitude Chambers
OMSF SPD No. 4	Safety Guidelines for Man-Rating Hyperbaric Chambers
-	NASA/AEC Interagency Agreement - Isotopic SNAP Devices for NASA Vehicles, September 1965
SP-3006	Bioastronautics Data Book
TM X-53328	Terrestial Environment (Climatic) Criteria Guideline for Use in Space Vehicle Development

2.3 KSC DOCUMENTS

The following KSC documents contain information that is directly applicable to KSC.

K-AM-02	Apollo/Saturn Logistics Support Requirements Plan
K-AM-05	Apollo/Saturn Reliability and Quality Assurance Program Plan
K-V-053	Apollo/Saturn V Ground Safety Plan - Volume II, Supplement II - KSC SNAP-27, Radiological Control Plan

K-V-053	Volume II, Supplement II, Appendix H - KSC SNAP-27, Contingency Plan (To be issued as a KMI)
-	KSC Facilities Plan for SNAP-27, Fuel Release (to be issued as a KMI)
KAPL	Kennedy Approved Parts List
KHB 4430.1	KSC Equivalency List
KMI 1050.1	MSFC/KSC Relations Agreement
KMI 1052.1	KSC/AFETR Joint Operating and Support Agreement
KMI 1710.1	KSC Safety Program
KMI 8838.1	Fire Protection, Prevention, and Rescue
KSC-GP-364	Index of KSC Specifications and Standards
KSC-GP-435	Drafting Practices and Design Data Manual
KSC-P-127	Packaging, Packing, Marking for Shipment and Storage of Ground Support Equipment
KSC-SPEC-F-0006	Heat and Blast Protection Coating Materials
KSC-STD-118	Failure Effect Analysis of Ground Support Equipment
KSC-STD-122	Determining Criticality Numbers for Priority I, II, and III Components
KSC-STD-E-0002	Hazard Proofing of Electrically Energized Equipment
KSC-STD-E-0012	Bonding and Grounding
KSC-STD-E-0013	Lightning Protection
KSC-STD-E-0015	Marking of Ground Support Equipment
KSC-STD-F-0004	Fire Protection Design for Facilities
KSC-STD-S-0002	Identification and Color Coding of Compressed Gas Cylinders

KSC-STD-S-0003	Color Code for Shop Machinery and Equipment
KSC-STD-S-0004	Color Coding of Fluid Systems Piping
KSC-TM-584	Corrosion Control and Treatment Manual
SP-4-38	Acoustic and Vibration Environment and Test Specification Levels, LC-39 GSE
SP-4-425	Microwave and Radar Hazards Handbook

2.4 MILITARY DOCUMENTS

The following military documents contain additional information on a specific subject.

MIL-B-5087 (ASG)	Bonding, Electrical, and Lightning Protection, for Aerospace Systems
MIL-E-6051	Ele romagnetic Compatibility Requirements, Systems
MIL-HDBK-472	Maintainability Prediction
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-171	Finishing of Metal and Wood Surfaces
MIL-STD-454	General Requirements for Electronic Equipment
MIL-STD-461	Electromagnetic Interference Characteristics, Requirements for Equipment
MIL-STD-462	Electromagnetic Interference Characteristics, Measurement of
MIL-STD-889	Military Standard, Dissimilar Metals
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment Facilities
USAF AFSC DH 1-6	System Safety
USAF AFM 127-1	Safety Manual
-	Armed Forces Explosive Safety Board Criteria for Siting of Facilities

2.5 OTHER PUBLICATIONS

The following publications contain additional information on the associated subject.

-	Walsh-Healey Public Contracts Act
Volume 1, No. 10	National Fire Protection Association, Fire Codes
Volume 34, No. 96	Department of Labor Safety and Health Standards, Federal Register
No. 704M	National Fire Protection Association Standard, Recommended System for the Identification of the Fire Hazards of Materials
Textbook	Reliability Engineering, ARINC Research Corporation, Prentice-Hall, Inc. 1964
Textbook	Reliability Handbook, Ireson, McGraw-Hill, 1966
IDEP	Interagency Data Exchange Program

SECTION III
REQUIREMENTS

3.1 GENERAL

All equipment and facilities at KSC are used, directly or indirectly, to receive, prepare, and launch space vehicles. Cost effectiveness is mandatory and includes not only the initial price of material items, but also how effectively these items can be used and maintained. Efficient operational and maintainability characteristics are key factors in meeting mission requirements at KSC, and must therefore receive prime attention from the designer.

3.2 OPERABILITY

The quality of a design is determined by the efficiency of the equipment being utilized. Equipment must not only perform the assigned function but, to be efficient, must not present unusual problems that compromise operations and maintenance. The objective is to provide equipment that represents the simplest design, consistent with the functional and environmental requirements. Therefore, the designer shall consider the three prime prerequisites, in the following order:

a. Simplicity of operation

b. Simplicity of maintenance

c. Simplicity of construction

3.3 RELIABILITY

The design of operational hardware/equipment shall be oriented toward effecting the greatest mean time to failure along with the shortest mean time to repair. The use of proven parts is preferred along with high reliability and appropriate screening of the components. Reliability can be affected by almost every decision the designer makes and the factors that he neglects. Generally, the best reliability will result when the designer employs good design techniques in all the areas presented in this document. The following three areas must receive special considerations:

a. Checkout or monitor equipment used to determine operability of critical equipment must be designed to be as reliable or more reliable than the critical equipment involved.

b. Single-failure points will be identified in all launch-critical systems where a single failure will result in a potential or actual catastrophe, or abort (scrub), of the mission. All launch-critical systems shall be subjected to the analysis described in KSC-STD-118 and KSC-STD-122. Additionally, Priority I or S component/equipment (whose failure can cause loss of vehicle or human life, or result in hazards to astronauts) shall either be eliminated by design or justified and documented as acceptable on the basis of qualitative engineering data.

c. Design checklists should be used by designers to ensure that the appropriate aspects of the problem are covered. Checklists suitable for this purpose are referenced in applicable documents contained in Section II.

Six of the many available methods for improving reliability during the design phase are presented in paragraphs 3.3.1 through 3.3.6.

3.3.1 Derating. The best methods for improving reliability, space or cost limitations permitting, are derating or overdesign of components or systems. Generally, the life of most parts continuously increases as the stress level is decreased below the rated value. Theoretically, the more a part is derated, the longer it will last. Practically, however, derating cannot be arbitrarily applied, for it is equally dangerous to under-rate as it is to over-rate. Either could be catastrophic unless special attention is paid to the location and application of the proposed item. The criteria for three major areas are as follows:

a. Structural: Design item to support load well over maximum specified load.

b. Electrical: Design electrical components to have higher ratings than actual usage values. Certain types of components, such as resistors, diodes, or capacitors, may be derated for use at approximately 50 percent of actual rated wattage or voltage, dependent upon the type of equipment and specific applications. In the case of more expensive components such as ac Power System transformers, the usage value (with consideration for future expansion) should be less than 100 percent of rated load.

c. Hydraulic/Pneumatic: Design pressure vessels to hold higher pressures than the maximum specified.

When derating is utilized by a designer, it should be clearly defined in the design reviews and in the technical data made available to the operator and maintenance personnel. When defining derating, the designer should remember that such action, by itself, does not eliminate single-failure points even though the probability of a failure has been reduced.

3.3.2 Redundancy. The method of redundancy involves the use of two or more functional paths or products rather than a single functional path or product to achieve a higher level of reliability. This reduces the probability of system failure due to single component failures, i.e., if one of two items fails, the second takes over the required function. Redundant elements may be either active or passive. Incorporation of simple parallel redundancy can improve the reliability one order of magnitude in some cases, with the addition of a redundancy element. For example, if one assembly had a reliability of 90.0 percent, putting two assemblies in parallel would yield a reliability of 99.0 percent and three assemblies in parallel would yield 99.9 percent. This acceptable method is frequently used at KSC in launch-critical systems where a failure would result in a catastrophic condition or a scrub of the mission.

The critical application of this method must be exercised by the designer. It is possible to degrade operability and/or maintainability to the point where reliability would be decreased under certain operational conditions. The very nature of redundancy allows certain failed or defective redundant assemblies to escape detection during normal system checks (because the system operation is not impaired with redundant assemblies). Designers must clearly identify and properly document adequate monitoring points to visibly warn or indicate failed or redundant assemblies, and to prevent dangerous depreciation of system reliability.

3.3.3 Simplicity. Simplicity should be a major objective of equipment design. An uncomplicated design (least number of components) which meets all system performance requirements is generally more reliable.

Proper packaging and layouts for accessibility can be introduced into more complicated systems, including those where redundancy is desired, thereby providing simplicity.

3.3.4 Standardization. The design of controls, displays and arrangement schemes (equipment and panel layout), coding, and labeling, etc., should be uniform throughout the entire system.

The use of standard components enhances system reliability, because they usually have been debugged and their performance characteristics are known widely throughout industry.

3.3.5 Testing. Reliability involves building up confidence, on the basis of factual data obtained from various tests performed. Production and field testability are of utmost importance, and the designer should strive to create a design which can be subjected to full nondestructive functional checkout.

The designer is responsible for ensuring that qualification test programs produce useful results and help prove the required degree of reliability. The test program must incorporate test results, past experience, and state-of-the-art development from similar programs to avoid unnecessary testing of parts/components. In part development and component qualification testing, performance criteria should be as similar as possible to the actual application.

Test samples must be of adequate number to be significant. Care must be taken to ensure that all tests performed are consistent and compatible to the intended use of the parts/components.

Additional reference information is contained in IDEP and KAPL.

3.3.6 Inspection. The following inspection methods should receive prime attention from the designer:

a. Areas of critical wear and deterioration in a component or system should be readily accessible in the field for inspection.

b. Critical dimensions, surfaces, finishes, and other nonfunctional attributes, up to and past the assembly point where they are likely to be degraded, should be accessible for inspection.

3.4 MAINTAINABILITY

The efficiency of KSC is enhanced by the ease with which equipment and facilities can be maintained. The designer shall adopt the following concepts to improve the maintainability efficiency during early design phase.

a. It shall be a design goal to reduce the potential complexity of maintenance by:

(1) Providing adequate accessiblity, work space, and work clearance.

(2) Providing for interchangeability of like components, materials, and parts within the system/equipment.

(3) Utilizing standard parts and items within the GSA/DSA/NASA supply inventories, where possible.

(4) Limiting the number and variety of tools, accessories, support equipment, and support facilities.

(5) Ensuring compatibility among system equipment and facilities.

(6) Providing isolation and vent valves in piping systems to permit maintenance and shutdown in case of an emergency.

(7) Designing pressure-reducing stations with redundant regulating branches in which the piping in each branch is routed to provide components removal(s), without removal of other branches from service by depressurization.

(8) Designing fluid piping systems with adequate number of mechanical connections to allow the isolation of the piping system into subsystems (for hydrostatic test and cleaning purposes). Drain valves should be provided at all low points in the pipe system to facilitate hydrostatic test and cleaning. Vent valves should be provided at any high point traps to facilitate bleeding air from piping system during hydrostatic test.

(9) Avoiding, where possible, system deadends (to facilitate system cleaning).

b. The designer shall seek to improve the maintainability of the product of the design by reducing the need for and frequency of design-dictated maintenance activities by:

(1) Utilizing fail-safe operational features.

(2) Utilizing components which require little or no preventive maintenance.

(3) Specifying tolerances which allow for use and wear throughout system design life.

c. To reduce the maintenance downtime, the following design factors shall apply:

(1) Rapid and positive detection of malfunction or degradation.

(2) Rapid accessibility.

(3) Rapid and positive localization of malfunctions to the repair level for which skills, personnel spaces, and test equipment are planned.

(4) Ease of fault correction.

(5) Rapid and positive adjustment and calibration.

(6) Rapid and positive verification of correction of fault.

d. To reduce design-dictated maintenance support costs, the designer should limit the need for extensive maintenance technical data and also the requirements for depot or factory maintenance, consistent with system effectiveness.

e. The maintenance personnel requirements should be diligently limited by applying the following sound human engineering principles:

(1) Identification and accessibility of parts, test points, adjustments, and connections.

(2) Logically sequenced maintenance tasks.

(3) A feasible range of relevant personnel physiological parameters.

(4) A reduction of the potential for maintenance error, by designing to eliminate:

(a) The possibility of incorrect connection/assembly/installation.

(b) Ambiguity in maintenance labeling, coding, and technical data.

f. Additionally, based upon maintainability prediction analysis data and actual maintenance experience at KSC, designers should place emphasis on:

(1) Designing involved equipment to provide a capability of at least 28 hours of uninterrupted operating time during a launch countdown without having to be calibrated, realigned, etc.

(2) Identifying the worst failure modes, and attempting to compensate for such conditions.

(3) Considering the possibility of future growth, and allowing for this capability if feasible.

(4) Providing mechanical and electrical interchangeability between like panels, assemblies, subassemblies, modules, units, and component parts.

(5) Providing layouts that permit, to the maximum degree, every component and assembly to be verified during checkout, without disassembly or disconnection of cables and components, and to have the capability of being checked out or repaired independently of other systems or components. Consideration, within reason, should be given to the replacement of subassemblies, to help eliminate extensive major assembly removal and replacement operations. The layout and design should be such that the majority of critical or primary components in a system can easily be reached and removed, without requiring teardown of adjacent systems to gain access to the defective components.

(6) Providng the capability to fully test active redundancy without disconnections or special test setups, where redundant circuits are utilized. Switchable redundant component circuits are desired over highly simplex circuits or Triple Modular Redundant (TMR) voting logic.

(7) Ensuring, where feasible, that it will not be necessary for components to be checked to the individual design specification or tolerance level during operations, but checked only for operability. Systems should be capable of being checked for overall mission accuracy requirements.

(8) Ensuring that design consideration provides strategically placed isolation valves in piping systems, to prevent outage difficulties and increase reliability.

(9) Providing sufficient status indication.

(10) Ensuring that lubrication points are accessible and clearly marked.

(11) Providing adequate field cleaning capability in fluid/gas systems to eliminate the need for extensive system teardown.

(12) Ensuring that tuning instructions and calibration charts are mounted on the equipment, when such instructions and charts are required for repeated usage.

(13) Designing equipment with multiple printed circuit module boards for removal and insertion (of module boards) with power applied without resultant damage to equipment, provided this does not appreciably increase the complexity. Boards should be physically removed from surrounding high-voltage or other critical circuits, so as to limit risk of harm to equipment or operator.

(14) Ensuring that hinged or door type covers are provided with slip hinges and stops to hold them open.

(15) Providing a printed circuit module testing capability.

(16) Providing adequate wet wells to eliminate the need for overflow pond for sewage lift stations for emergency.

(17) Generally utilizing ceramic cooling towers for air conditioning in lieu of wood or combined wood and steel.

3.5 MAINTENANCE AND REPAIR

Maintenance and repair can be basically classified as preventive (fixed on a predetermined time cycle and procedure before a failure is expected to occur) and unscheduled (unanticipated) failure. Efficient operations should require minimal preventive and unscheduled maintenance, thereby increasing the operational flexability at KSC. Launch operations are based on a schedule of events over the allotted time and usually are presented in time-based bar charts (waterfall). Access to equipment is a direct function of the activity in the area and/or the launch status of the space vehicle based on the potential hazards to both personnel and equipment.

Program requirements, readiness for launch, and material characteristics of the space vehicle (such as fuel loading rates) impact maintenance and repair schedules. These three basic constraints must be recognized by equipment designers for they dictate such factors as minimum operating time between repair cycles and reliability.

The importance of preventive maintenance increases with the criticality of the system. The greater the effect of a system on hazards prevention and mission success, the more important it is that unscheduled failures not occur (good reliability plus a maintenance cycle that will tend to prevent any deterioration of that reliability). The designer shall provide quantitative recommendations, preferably based on test results, from which effective preventive maintenance procedures can be developed.

The designer should also provide adequate maintenance test information, recognizing that GSE Component Specification Control Drawings are intended primarily as procurement and qualification requirement documents for new hardware, rather than for maintenance use. The test procedures called out on these drawings are:

a. Not to be used as the absolute recycle test procedure.

b. The basis for information to write operating procedures for postmaintenance bench testing, etc.

3.6 PROJECTED USEFUL LIFE

The characteristics of the product of the design plays the major role in determining the potential projected useful life. The designer must therefore adjudge the operational requirements and environmental conditons which are to be imposed on the finished product, before initiating the design effort. Electrical/electronic launch support equipment is most prone to early obsolescence but, in any event, should have a useful life of at least 10,000 operating hours. Heavy equipment should have useful lives extending upward to 20 years, and permanent facilities should last up to 40 years. The conceptual phase of each design effort must include trade-offs to establish meaningful, useful life goals for that particular effort, based on projected program requirements and possible follow-on usage.

3.7 ENVIRONMENT

The environmental requirements, natural and induced, are presented in paragraphs 3.7.1 and 3.7.2. They include the protection, where possible and feasible, of equipment and facilities from extreme environments during operational use. Additionally, the designer must identify and properly document the requirements for environmental protection of components during shipping and storage.

3.7.1 Natural Environment. The natural environment at KSC is semitropical and very high (in comparison to the rest of the continental United States) in moisture content, presence of corrosive salts, and extent of lightning. A relative humidity of 100 percent and temperatures from 30° to 100° Fahrenheit are common.

The end use of equipment dictates the environmental characteristics which the equipment must withstand when in operation. Controlled environments are present in Launch Control Centers and similar areas containing critical equipment that requires special protection. The designer must ascertain in which area the equipment will be installed prior to proceeding with design.

Noncontrolled environment buildings may exhibit higher inside temperatures than are experienced on the outside. The designer must consider on-site (KSC) storage conditions (paragraph 3.11), as well as the installed conditions, and specify protective packaging (of the marine type) if the equipment will be subjected to storage prior to its intended usage in a controlled environment. Other equipment that must be operated in the natural environment should be designed accordingly.

Roof surface design criteria should allow additional margin to compensate for the flash flooding which may occur in this area. Original designs of drains should provide for future additions and thereby decrease the probability of restricting the flow from roofs. Additionally, the original roof design should provide walkways to the existing roof facilities. Added roof facilities (such as antennas) should include adequate walkways to the facility for maintenance personnel and should decrease the probability of damage to the roof.

3.7.2 Induced Environment. The designer must know in advance how close the equipment and/or facility being designed will be to one (or more) of the launch pads. From the time of ignition until the launch vehicle leaves the geographical limits of the Center, the engines will emit heat and also subject everything within range to an acoustical and vibrational environment. Equipment mounted on the pads and umbilical towers will also be subjected to deposits consisting of the products of combustion; consequently,

these chemicals must be identified and their corrosive characteristics known in advance. Equipment must be either expendable or designed to withstand these induced effects, in addition and conjunction with other specified requirements.

The designer must have definite data on the exhaust characteristics of the launch vehicle, or may use existing data that most closely approximate the situation. These data are contained in SP-4-38-D (for Saturn V) which also contains data on acoustical sound pressure levels and vibration "g" levels as a function of frequency. Such data should be used for design purposes and to establish test requirements.

Components and hardware installed in launch or blast danger areas are subject to damage by flying objects; consequently, adequate guards and protective devices should be provided.

3.8 TRANSPORTABILITY

Designers must consider the many transportability requirements for all equipment. Racks of equipment, consoles, etc., should be designed to permit the breaking of connections between elements to facilitate their placement in their operating area. Whenever possible, equipment should be packaged for transportation by common carrier (truck, rail, or plane), and all equipment must be capable of withstanding all forces, shocks, and environments encountered during transportation. Designers should strive to adapt electrical/electronic components for hand-carry features. Facility design factors include the provision of adequate clearance for movement of equipment in and out of enclosed areas, depending upon the designated use of the installation.

Upon determination of utilization and location of the equipment, the designer should attempt to minimize installation and removal problems whenever possible. This can be accomplished by providing equipment which can be lifted by commonly available forklifts or cranes and can fit into standard elevators and through doorways, and by other similar factors as applicable. Suitably labeled handholds and/or lifting lugs shall be provided to facilitate movement of bulky and/or hand-carry items. Portable equipment shall be physically (size and weight) compatible with existing facilities (elevators, catwalks, etc.) in the area of intended use. Additionally, provisions for securing (tiedown lugs, brakes, etc.), and grounding provisions (as appropriate) must be available.

Hazardous items (explosives, high-pressure gases, etc.) must be provided in transport containers that comply with the civil laws (of the area through which they are shipped) and the appropriate KSC safety regulations. Other items requiring a special environment (such as purge or temperature conditioning) shall be delivered in containers suitable for this purpose. These containers must be provided with lifting and holddown lugs, plus the means for determining (by a cursory examination) that the special environment is being maintained.

3.9 HUMAN PERFORMANCE

Equipment designers must take into consideration that men must install, operate, and maintain these items. Therefore, equipment must be provided that is compatible with human capabilities. If these requirements cannot be met, the design organization must make this fact known to KSC management prior to the start of hardware manufacturing or construction.

All equipment must encompass sound human engineering considerations; equipment operation should be straightforward, logical, and unsusceptible to erroneous or inadvertent operation as a result of operator error. Equipment operators should have reasonable access (within reach and audio-visual range) to controls and/or displays necessary to good operational practice. Personnel must be able to gain access to the equipment for maintenance or operational purposes.

Special considerations must also be given to prevent the following undesirable factors which may be introduced through design errors:

a. Lack of conformance to population stereotypes, such as clock hands that rotate left instead of to the right.

b. Human reaction that exceeds the physical and psychological limits of the average man.

c. Accelerated fatigue due to such things as the requirement for maximum reach, eye strain, or the lifting of heavy objects.

d. Failure of equipment to provide adequate information for the operator to perform an assigned task, such as the wrong or ambiguous tolerances in a pressure gage or electrical meter.

e. Unnecessary difficult or unpleasant tasks, or monotonous repetitive operations, such as constant readjustment of a setting due to slight influxes from interrelated gear.

f. Unnecessary dangerous tasks that may require a man to risk his life or health.

f. Unnecessary unpleasant environments such as excessive noise or heat.

Additional reference information is contained in the following documents:

a, Bioastronautics Data Book, NASA SP-3006

b. Human Engineering Design Criteria for Military Systems, Equipment Facilities, MIL-STD-1472

c. System Safety, USAF AFSC DH 1-6

3.10 SAFETY

The almost constant presence of humans in all areas of this Center requires that the designer make every reasonable effort to provide fail-safe equipment and minimize the possibility of compromising the lives and safety of personnel, or of damaging equipment. These factors are closely related to, and should be considered in conjunction with, the human factors presented in paragraph 3.9. In addition, designs shall employ features for the protection of operating and servicing personnel. Considerations shall be given to such features as:

a. Illumination to ensure proper operator visibility.

b. Accessibility.

c. Elimination of exposed electrical potentials, sharp edges, and protrusions.

d. Interlocks where lethal voltages, pressures, or vapor exist.

e. Rotation of equipment guarded to prevent accidental entanglement of personnel.

f. Tamper-proof electrical panels for launch-critical facilities.

g. Proper identification of hazardous materials.

Fail-safe and/or operational design systems, both control and monitoring, should be designed such that component failure will not only result in a safe system but

will provide a system in a configuration giving the most desirable support. (In certain cases, it may be more desirable to have a system operate in a noncontrol status than be shut off.)

Any equipment that could produce an ignition source (sparks, heat, etc.) that is to be used in the proximity of explosives, fuels, and/or oxidizers (LH_2 or LOX Systems), shall include provisions for hazard-proofing in accordance with KSC-STD-E-0002. If the equipment is to contain, transfer, or control materials such as gaseous hydrogen or liquid oxygen, the housing should be such as not to contain or confine any explosive materials that might accumulate from leakage.

Designs for distribution systems shall provide means to preclude inadvertent intermingling of their products. Safety considerations are required not only at the component level, but also when equipment is joined together to form systems and/or subsystems. This requires consideration of the fact that when two or more elements with no undesired characteristics are joined, an unsafe condition may be created.

For successful launching of space vehicles at this Center, selected elements of launch equipment and facilities must be man-rated. This can be accomplished by the usage of prior launch data, proof of meeting documented criteria, and/or special tests. The extent of this activity is dictated by the degree of potential hazards that exist, in spite of the best efforts of the designer. The designer shall be responsible for identifying such hazards.

Storage of hazardous material (propellant, explosives, etc.) shall be in conformance with the Armed Forces Explosive Safety Board Criteria for the Siting of Facilities, which includes the requirements regulating the use of pressurized vessels.

Additional safety reference information is contained in the following documents:

a. Safety Program Directives, OMSF
b. System Safety, USAF AFSC DH 1-6
c. NASA Safety Manual, NASA NHB 1700.1 (IV)
d. Fire Protection, Prevention, and Rescue, KSC KMI 8838.1

e. KSC Safety Program, KSC KMI 1710.1

f. Hazard Proofing of Electrically Energized Equipment, KSC-STD-E-0002

g. Fire Protection Design for Facilities, KSC-STD-F-0004

h. Bonding, Electrical, and Lightning Protection, for Aerospace Systems MIL-B-5087 (ASG)

i. National Fire Protection Association, Fire Codes, Volume 1, No. [illegible]

j. Department of Labor Safety and Health Standards, Federal Register, Volume 34, No. 96

k. Walsh-Healy Public Contracts Act

3.10.1 Water Deluge. Utilization will be made of existing water deluge systems to:

a. Provide a washdown after inadvertent fuel or propellant spills (provided the water does not react in an undesirable manner with the spilled compound).

b. Protect the on-pad facilities from the blast of the launch vehicle engines.

c. Control fires (when water is the proper agent).

In view of the problems associated with the undesirable use of water deluge systems, it is imperative that designers place emphasis on designing such systems in a manner that will prevent inadvertent actuation of any such systems. Design features shall include assurance that actuation of such a system is a deliberate, premeditated act by a single individual. The indiscriminate use of water can:

a. Damage the space vehicle.

b. Wash compounds into an area that would provide additional danger or unnecessarily damage equipment or facilities.

c. Dilute the effectiveness of other firefighting agents that may be more suitable for use under a given condition.

d. Intensify the condition by an undesirable reaction with certain materials in the area.

3.10.2 Radiation Hazards. The design of devices using radioactive materials in quantities that can, in the event of accident, result in contamination of the adjacent areas, is subject to the control of the Atomic Energy Commision (AEC). The involvement

of KSC designers and/or the operating personnel with such devices is handled through documents similar to the NASA/AEC Interagency Agreement-Isotopic SNAP Devices for NASA Vehicles, September 1965. Requirements vary widely depending upon the type of device under consideration, and are therefore not covered by this document. A concept of the restraints placed upon the operators handling such equipment is outlined in the following documents.

a. Apollo/Saturn V Ground Safety Plan (Appendix H to Supplement II to Volume II, K-V-053, KSC SNAP-27, Contingency Plan) (to be issued as a KMI)

b. Apollo/Saturn V Ground Safety Plan (Supplement II to Volume II, K-V-053, KSC SNAP-27, Radiological Control Plan)

c. KSC Facilities Plan for SNAP-27, Fuel Release (to be issued as a KMI)

Protection from radiation from electronic devices is also required. Such design requirements are covered in various MIL Standards and Specifications, and in KSC Handbook SP-4-42S, Microwave and Radar Hazards Handbook.

3.11 LOGISTICS

Logistic requirements vary between programs/projects. The Apollo requirements are called out in NASA NHB 7500.1 and NHB 7500.2, and in KSC K-AM-02. It is uneconomical to establish large maintenance inventories at operational bases such as this Center, since most warehouses lack environmental control, and because of the high cost involved in providing storage space.

Emphasis should be placed on "black box" replacement, low failure rates, and standardization. Spares shall be delivered with new equipment or be available from standard stock sources.

Facility designers shall provide for easy access to all buildings for delivery of material, including loading ramps or other suitable accommodations for trucks to load and unload. Any structure will require logistic support of some type, so provisions must be made to facilitate movement of supplies.

3.12 DOCUMENTATION

The designer shall produce adequate design drawings for the manufacture or construction of components and also any of the following, as applicable:

a. Test plans and/or procedures

b. Adequate technical data for use by operators

c. Data required to support necessary logistics and maintenance

The technical data provided should generally be reproducible, and consideration should be given to including the following applicable documentation:

a. Block or logic diagrams

b. Double-ended schematics

c. Logic equations

d. Wire/cable lists and diagrams, and complete parts lists

e. Applicability documents

f. Module board schematics and performance characteristics

g. Software documentation, such as flow charts, listings, operating instructions

h. Specification and tolerance lists

i. Test specifications and procedures (man-rating, acceptance, maintenance)

j. Procurement specifications (for logistics)

k. Complete design drawing package

l. Operating criteria (parameters)

m. Operations and Maintenance (O&M) manuals and handbooks

When vendor and commercially available parts are utilized, the designer shall obtain and include in the design data package sufficient information to permit replacement manufacture in the event the vendor goes out of business or discontinues the item. The designer should identify all handling, installation, and operational conditions which are critical to the component or system, and ensure that this information is supplied by formal documentation to the appropriate people (e.g., Operation & Maintenance Manuals).

Additional reference information is contained in Drafting Practices and Design Data Manual, KSC GP-435.

3.13 DESIGN AND CONSTRUCTION

The program/project management will select the basic guidelines for the designer. The selection of the specifications and standards required for design and construction of the component is a combined program/project and designer function. The selected pertinent documents are used to support the design drawings to control manufacture, and for test and acceptance of the component. In each design effort, additional requirements are imposed as dictated by the individual program/project direction. The information presented in paragraphs 3.13.1 through 3.13.14 are the minimum requirements that a designer of equipment and facilities should recognize and meet.

3.13.1 Basic Requirements. Facilities and systems shall be designed to the highest standards of industry. Experience has shown that special attention must be given by the designer to the following general design and construction requirements:

a. Designs that will facilitate placement and removal of equipment.

b. Ease of access to equipment and components by maintenance personnel.

c. Use of standard available equipment.

d. Redundancy in the design of a component or system, as applicable, when concessions must be made in reliability of launch-critical or test-critical components/systems.

e. Designs adequate to obtain the required performance under all applicable environmental (natural and induced) conditions.

f. Operating area noise suppression.

g. Automatic checkout capability, where feasible. Systems to be checked out by computer control shall be compatible with the computer systems.

h. Information displays for the operator.

3.13.2 Materials/Parts/Process. In materials selection, the designer shall obtain knowledge of the material properties and also the behavior in the environmental states in which it will be utilized. Although the choice of material in critically designed parts is

judged by the performance of that material when in use, it is preferred that when in the preliminary design phase, the designer use appropriate data obtained from standardized tests. In addition, an analysis is to be made of the conditions under which the test data were obtained, and to use the data most pertinent to anticipated service conditions.

The anticipated usage and the operating environment of the proposed component are critically important during the selection of materials. The designer should utilize information sources such as the Interagency Data Exchange Program (IDEP), and commercial literature to seek the best combination of properties and cost in the materials selection. The determining factors fall into two groupings: Group A, function, stress, and weight; Group B, manufacturing, cost, and maintenance. Group B usually determines the final selection when more than one material satisfies the related requirements applicable to Group A. Special attention shall be given to the non-use of materials that are not readily workable, and the use of standard production facilities and techniques.

Standard commercial processes should be specified where applicable and excessive treatment should be avoided. Processes shall be based on best industrial practices and approved methods. Due to the mechanical, thermal, and metallurgical treatments of metals, it is often advantageous for the designer to determine the nature of the induced internal stresses, and the processes of stress relief of the material.

Additional information for reference is contained in the following documents:

a. Interagency Data Exchange Program, IDEP

b. Index of KSC Specifications and Standards, KSC GP-364

c. Heat and Blast Protection Coating Materials, KSC-SPEC-F-0006

3.13.3 Standard/Commercial Parts. Designers should emphasize the use of commercially available qualified items for standard off-the-shelf replaceable parts such as transistors, standard hardware, screws, nuts, bolts, etc., to simplify maintenance and repair. Cost effectiveness, through standardization in operating areas, is a long-standing industrial practice that shall be used by designers. The designer shall determine the operational requirements (how it will be used) of the equipment or facility prior to parts selection. This will provide the base needed to determine whether standard parts

can or cannot be utilized. Liberal use shall be made of applicable documents (QPLs, KAPL, IDEP, KHB 4430.1, etc.) to reduce maintenance, logistic, and training workloads, in addition to the consideration of initial costs.

The following unfavorable conditions shall be avoided as much as possible in the interests of economy:

a. Extensive parts inventories.

b. Special purchases of unique items not readily available or requiring special low-volume production which may force a vendor to acquire special tooling.

c. Extensive training of personnel to cope with wide variety of parts.

d. Long maintenance turnaround times due to lack of standardization.

Additional reference information is contained in the following documents:

a. Qualified Parts List(s), QPLs (on available and applicable parts/subjects)

b. Kennedy Approved Parts List, KAPL

c. KSC Equivalency List, KHB 4430.1

d. Interagency Data Exchange Program, IDEP

3.13.4 Interchangeability/Replaceability. Whenever possible, interchangeability of like and/or similar function items is a basic requirement for the designer in the early stages of design. This is required as a basic means for achieving efficient and effective logistic support, and control of replacement costs. Tremendous cost savings can be achieved in quality testing, maintenance, refurbishment, spare parts supply, etc., by using like components to the greatest extent possible. In some instances, it may be less costly in the long run to select a more expensive component for a design (when this component is in multiple use in other design areas) than to select a cheaper item (even when the cheaper item would satisfactorily fulfill the requirements).

In the area of flexlines, the design should be centrally controlled in the design organizations to reduce the number of different flexline sizes and length to a minimum.

Replaceability demands not only reasonable access to a failed unit but availability of replacement units in the logistic support system. Items having a unique location use (one place only) add expense to operational activities for the following reasons, and every reasonable effort should be made by the designer to limit their use.

a. Low-volume production costs.

b. Need for special storage space (separate from common stock items).

c. Additional administrative workload.

d. Additional cost of training technicians.

3.13.5 Moisture/Fungus Resistance. The natural environment at this Center provides very favorable conditions for moisture and fungus to produce undesirable results. Materials which are not nutrients for fungus shall be used whenever possible. The use of materials which are nutrients for fungus is permitted in controlled environments (such as hermetically sealed assemblies) and other accepted and qualified uses, such as paper capacitors and treated transformers. If nutrient materials must be used in other than such qualified applications, they must be treated by a method which will render the resultant exposed surface fungus-resistant.

Materials sensitive to moisture (changes the physical characteristics) or those that tend to hold moisture and thereby induce corrosion or electrical problems shall:

a. Have adequate protective coatings or shall be used only in a controlled environment.

b. Be used in configurations that will not trap or hold moisture (unless this is a specific design objective).

3.13.6 Corrosion. The atmosphere at this Center contains a high salt content that is readily deposited on exposed surfaces. This, combined with substantial rainfall, steady winds, low land elevation, and generally high temperatures, results in an ideal environment for extensive corrosion of metals. These conditions are severe for both electrolytic action and chemical reactions, dependent upon the metal(s) involved and how it is utilized. Although corrosion control is primarily the responsibility of the maintainer of the equipment, the designer is responsible for providing hardware that will not present unnecessary problems.

The designer must determine where the resultant item/component will be located at KSC. Such locations can vary from the severe conditions present on an umbilical tower (fully exposed to the elements), to the partially controlled environments provided in air-conditioned rooms, to the carefully controlled conditions in a clean room. The designer shall be primarily responsible to utilize every reasonable technique to ensure that the design provides for:

a. Good protection from the environment.

b. An optimum choice of materials.

c. Avoidance of surface-to-surface contact of dissimilar metals.

All components and hardware to be installed in exposed environments must be treated to withstand the elements, i.e. KSC-recommended corrosion protection coatings on all metal surfaces; encapsulated motor windings; heater strip for moisture and condensation elimination.

Consideration shall also be given to the following:

a. Salt accumulation on metal that provides an undesirable electrical conductive path.

b. Hardware mounting bolts, brackets, and fixtures to eliminate or minimize galvanic corrosion.

c. Equipment designed to prevent trapping condensation and rain which serves as a point from which corrosion starts.

If, for cost effectiveness reasons, it is not feasible to provide fully adequate corrosion protection as a part of the design, the designer shall notify KSC management of the special support requirements which must be met. Such support requirements may vary from special preventive maintenance to providing special packaging (such as an air-conditioned cabinet) and must be presented in time to permit the orderly funding, design, and manufacture of any necessary hardware or facilities.

Additional reference information is contained in the following documents:

a. Terrestrial Environment (Climatic) Criteria Guideline for Use in Space Vehicle Development, NASA TM X-53328

b. Finishing of Metal and Wood Surfaces, MIL-STD-171

c. General Requirements for Electronic Equipment, MIL-STD-454

d. Corros[illegible] Control and Treatment Manual, KSC-TM-584

3.13.7 Electromagnetic Compatibility. All equipment in use at KSC is subject to electromagnetic interference monitoring to eliminate that which produces intolerable emissions. This can result in equipment shutdown and could compromise launch operations; such a situation would be unacceptable to management and must therefore be avoided. It is the responsibility of the designer to determine if the program for which the equipment being designed has any special Electromagnetic Compatibility (EMC) requirements. These requirements are closely related to the electrical design criteria, and these factors should also be considered during the design effort.

Equipment to be utilized at KSC shall provide a minimum of undesired signals to preclude interference with the operation of other equipment and/or systems, regardless of the proximity of such equipment to other equipment. Equipment must be designed to control any spurious (conductive or susceptive) emissions prior to the installation of such equipment. Suppression of Electromagnetic Interference (EMI), caused by switching inductive loads (such as solenoid valves and relay coils), requires special attention in the design phase. Incorporation of suppression measures after equipment installation results in substantially higher hardware and support costs.

Additional reference information on EMI and EMC is contained in the following documents:

a. Electromagnetic Interference Characteristics, Requirements for Equipment, MIL-STD-461

b. Electromagnetic Interference Characteristics, Measurement of, MIL-STD-462

c. Electromagnetic Compatibility Requirements, Systems, MIL-E-6051

d. Electromagnetic Compatibility Principles and Practices, NHB 5320.3

3.13.8 Workmanship. The designer must provide proper specifications to ensure that the quality of construction and finishing of the item (and its parts) is consistent with design objectives. This will prevent possible degradation of the design to the point that

the product may not meet the operational requirements. Such specifications can be provided by data on the design drawings, control specifications or standards, reference to published specifications, special manufacturing instructions, or any combination thereof. In any event, the designer must ensure that the requirements are specifically presented in formal approved documentation, which therefore cannot be ignored by suppliers and manufacturers.

3.13.9 Identification/Marking. Electrical or mechanical components in systems shall be marked with a permanent written identification that is identical to the identification provided in the associated documentation. Such identification (KSC-STD-E-0015) shall be adequate to permit easy location and recognition through the use of reference material (technical manuals, schematics, drawings, etc.). Racks, panels, consoles, and similar system (or subsystem) elements that are packaged as a unit shall also be similarly identified.

Color coding and written identification of materials in piping systems and compressed gas vessels (mobile or fixed installation) will be utilized to convey the necessary warnings (for safety purposes) and to minimize confusion under its operational conditions. The designer shall:

a. Ensure unmistakable identification of the contents of a system during operation.

b. Provide distinctive markings that will display visual warnings of dangerous piping systems, and indicate the type of hazard involved.

c. Mark pressure vessels to permit easy segregation, filling, using, handling, or storage.

All packages used for shipping and/or storage shall feature sufficient markings to permit ease in sorting and handling, without requiring reference to special technical documentation. The contents shall be identified, and notation made regarding storage and the environmental limitations. Such markings shall also indicate if hazardous materials are enclosed.

Additional reference information is contained in the following documents:

a. National Fire Protection Association Standard, Recommended System for the Identification of the Fire Hazards of Materials, No. 704M

b. Marking for Shipment and Storage, MIL-STD-129

c. Identification Marking of U.S. Military Property, MIL-STD-130

d. Marking of Ground Support Equipment, KSC-STD-E-0015

e. Identification and Color Coding of Compressed Gas Cylinders, KSC-STD-S-0002

f. Color Code for Shop Machinery and Equipment, KSC-STD-S-0003

g. Color Coding of Fluid Systems Piping, KSC-STD-S-0004

h. Packaging, Packing, Marking for Shipment and Storage of Ground Support Equipment, KSC-P-127

i. Packaging, Preservation and Marking Requirements for Aeronautical and Space End Items, Components, Parts, and Associated Equipment, NASA NMI 6410.1.

3.13.10 Storage. The storage area at KSC is limited and, for the most part, lacks temperature or humidity control. The designer shall avoid, where feasible, designs that require special storage or unique packaging. Therefore, the designer must be continually cognizant of possible limitations when selecting materials and recommending spares inventory and storage requirements. (Numerous items/parts have critical storage requirements/restrictions; certain chemical compounds have a usable shelf life and/or rigid environmental requirements.)

Equipment that utilizes parts and components of a sensitive nature, that will temporarily be stored prior to usage, should be identified. If possible, such special parts and components should be shipped in separate packages to ensure proper handling. Equipment may have to be stored outside for an indefinite period, and must therefore be designed to withstand (or packed for protection from) the natural environment.

3.13.11 Electrical. The design of new electrical facilities and equipment and alteration of existing electrical facilities and equipment at KSC shall meet the applicable requirements set forth in NHB 7320.1, the National Electrical Code, and the applicable KSC Specifications and Standards. Particular attention shall be given to coordination of electrical protective devices in launch-critical facilities to ensure that failures anywhere

in the power system will result in minimum loss of service to equipment served by the power system. Electrical/electronic equipment connected to the power system should be provided with protective de· ·es as required to protect the equipment (since the protective devices in the power system are designed primarily to protect the power system).

All electrical/electronic facilities and equipment shall be connected to a true earth ground either directly or through a grounding system network in accordance with standard KSC-STD-E-0012. Chassis ground in equipment shall not be common to a signal ground in the grounding system network. Designers shall ascertain that provisions are made, where appropriate, to provide for the following principles:

a. The prevention of localized abnormal voltage buildups which could injure personnel or damage equipment.

b. A discharge path that will preclude a buildup of static charges.

c. The prevention of radio frequency (RF) noise generation.

d. A conductive equipotential surface for a zero signal reference plane.

e. Utilization of structural metals for electromagnetic shielding.

Additional reference information is contained in the following documents:

a. Bonding, Electrical, and Lightning Protection, for Aerospace Systems, MIL-B-5087 (ASG)

b. Bonding and Grounding, KSC-STD-E-0012

c. National Electrical Code

d. Facilities Engineering Handbook, NHB 7320.1

3.13.12 Lightning Protection. Lightning protection shall be provided for buildings, structures, and similarly exposed equipment as a part of the grounding network. This requirement does not apply to buildings under 50 feet in height that do not contain critical equipment or explosive materials. Such protection will feature a metallic conductive path to ground rods, or a counterpoise, to preclude placing undue stresses on non-conducting parts during a lightning discharge. The provisions of the Fire Protection Association Fire Codes and KSC-STD-E-0013 shall be followed by the designer. Such requirements are necessary because estimates of the probability of structures being hit by lightning at KSC show an isokeraunic level of 75, as compared to a continental average isokeraunic level of 32.

3.13.13 Mechanical. The designer should be particularly aware of the material problems involved for systems, especially when the media is liquid oxygen, gaseous oxygen, liquid hydrogen, or hypergolics. The material problem also affects areas where other GSE is closely located to systems with the above media and is exposed to overflow, spillage, or leaks. The responsible design agency at KSC must be consulted for advice or approval for hardware, software, lubricating, and protective coating materials for systems with these medias. Material incompatibility has a direct effect on launch capability, and has been a major source of mechanical problems on the launch complexes.

Designers shall be responsible to ascertain provisions are made to provide:

a. Space limitations and maximum permissible floor loading at location(s) where equipment is to be utilized.

b. Pressure relief valves adequately sized to preclude overpressurization of the system and vent in a manner that is not hazardous to personnel.

c. Vacuum-jacketed equipment, piping, and vacuum jackets for components designed with reliability as the primary consideration and heat leak secondary, unless it is deemed that the latter is required for special application. (If vacuum-insulated systems are considered to be permanent vacuum, means of vacuum verification which would degrade the system should not be installed.)

3.13.14 Civil. The design of new facilities and alteration of existing facilities at KSC shall meet the requirements set forth in NPC 325-1 and NHB 7320.1. These requirements apply to permanent and semipermanent installations. Additionally, the safety requirements set forth in paragraph 3.10 shall apply, and there shall be compliance with NHB 1700.1 (VI), Volume I, and Article 1412 "Fire Prevention and Protection."

The heat, humidity, and precipitation characteristics at KSC also require that the designer give special considerations to:

a. Providing floor drain sump catch basins where it is possible that a large quantity of liquid may empty into them. (The failure of a sump pump without a catch basin can result in facility flooding before repairs are effected.) Where possible,

a gravity overflow line outside the building should be included to further ensure the prevention of facility flooding.

b. Designing large air-conditioning systems that allow for equipment expansion.

c. Locating septic tanks away from building roof drains (to avoid having the tank and drainfield absorbing surface water). An opening should be provided for possible future pumping. Prior to the design and proposed use of septic tanks, special coordination is required to obtain agreement between design, operation, and maintenance representatives. The continued use of such tanks shall be restricted in conformance with State and Federal Codes, and shall require the approval of the responsible directors at KSC.

d. Ensuring that all facilities conform to the latest State and Federal standards, for the reduction of air and water pollution.

3.14 INTERFACES

No item of equipment or facility at KSC is remote from all other items and/or personnel and must, therefore, interface with something definable. It is the responsibility of the designer to ascertain whether he shall establish the interface definition or work to the specific requirements provided by another source.

Interface definition, as used herein, includes physical (material-to-material contact), functional (pressure heads or voltage), and operational limitations (access when operating) parameters. This definition shall be transferred between design organizations by means of approved documentation to preclude unnecessary misinterpretation. This does not preclude liaison between design organizations, but makes it necessary to formally document the conclusions reached by the involved engineers.

SECTION IV
QUALITY ASSURANCE

4.1 GENERAL

The assurance that reliability, design characteristics, operability, and perfomance goals were attained is normally based on formal tests and verifications. Formal, herein, means the use of recorded plans and procedures prior to testing, and the recording of test results and conclusions subsequent to testing. Unless such recording is accomplished in a comprehensive manner, the true meaning of the test results is lost, becomes obscured, or is misleading and results in unnecessary loss of time and funds.

Testing for the purpose of qualification, reliability, and acceptance for delivery shall be accompanied by an appropriate inspection program (quality control). The basic concept for testing and inspection, and the purpose of these Apollo activities are presented in NASA Apollo Test Requirements documents NPC 250-1, NHB 5300.4(IB), and NPC 200-3. The degree and extent of testing and inspection must be geared to the criticality of the item when it is in operational use. The complexity, end use, and projected useful life must also be considered in determining the extent of these requirements. The fabrication standards, specifications, and qualification testing requirements must be identified by the designer and coordinated with the cognizant O&M and quality organizations at the time the equipment criteria are being firmed.

The designer shall identify the following inspection requirements and must coordinate these required inspections with the cognizant O&M and quality organizations.

a. During fabrication

b. During assembly

c. Prior to shipping

d. Receiving

e. Installation

f. Acceptance

The utilization of NASA and O&M Contractor operations personnel on a consultant basis, by the inspection personnel during these required inspections, usually results in an improved installation. It also provides the operations personnel with knowledge of the system and will improve the orderly turnover of the new equipment or facility. During these inspections, the quality control inspectors shall ascertain that the written approved requirements are met.

The integrated, engineering and evaluation, qualification, and reliability testing requirements are presented in paragraphs 4.2 through 4.5.

4.2 INTEGRATED TEST REQUIREMENTS

The various test requirements are established by program/project management and are contained in such documents as NHB 8080.1. These requirements are oriented toward the criticality of the equipment/facility, and consist of three categories:

a. Launch operation support.

b. Potential hazard to personnel.

c. Damage to other equipment/facility.

Design of new equipment/facilities that falls into any of these three categories shall require a high degree of reliability and operability, and must be verified by testing. The basic functional areas for testing are:

a. Research to improve concepts, methods, and materials.

b. Development of hardware concepts (to meet requirements/verify designs) prior to making manufacturing commitments. (This includes specific prototype development, engineering test, and evaluation.)

c. Manufacturing process, qualification, reliability, and acceptance testing prior to delivery of hardware for experimental/operational use, maintenance, and/or installation.

d. Receiving tests to ensure that the hardware is operating and is being properly installed.

e. Systems verification testing to establish operational readiness (usually accomplished by an end-to-end test of the functional path and resulting in verification of the functional interfaces).

The first three functional areas are within the scope of program/project direction and the responsibility of the designer. In addition, the designer shall make recommendations from which the remaining test procedures can be developed by the operators. The integrated test program must be developed during design phase, and constantly upgraded. The designer shall make the best use of the data obtained and make the best cost-effective trade-offs (between test needs and design goals). Maximum use must be made of each test area, by the subsequent test activities, to eliminate unnecessary testing and/or to acquire needed additional data.

4.3 ENGINEERING TEST AND EVALUATION

This functional area of testing is oriented towards providing the designer the opportunity to obtain empirical data to support or develop design concepts. The designer shall be responsible for:

a. Recording procedures and results (so that the data may be reviewed/ utilized for future use).

b. Planning tests in a systematic manner (to minimize cost, i.e., overtest or useless tests).

c. Ensuring, when feasible, that the results can be used (partially or fully) in subsequent reliability or qualification determination activities.

4.4 QUALIFICATION TESTING

Qualification testing should be performed only on components or subassemblies, except where an item is critical for mission success or safety purposes. The designer shall determine the hardware that requires such testing in conjunction with program/project management direction (such as NPC 250-1 and NHB 8080.1).

The designer must ensure that the test plans (and/or procedures) place rigid controls on the tests so that the resultant data can be properly evaluated. In addition, proper monitoring and inspection shall be required to ensure conformance to the test requirements and accurate recording of test results.

4.5 RELIABILITY TESTING

Components or items that will become Priority I or S single-failure point shall be subjected to reliability testing to obtain empirical data from reliability analyses. However, the reliability testing requirements should depend on program requirements, as well as reliability requirements dictated by lack of availability, access restrictions, and priority. Equipment not included in the above category may also require such testing depending upon the best judgement of the designer and program/project management.

The designer should avoid reliability testing as the sole means of obtaining such data. (In most cases, a carefully preplanned integrated test program should suffice.) When necessary, reliability testing should supplement other test data to produce the required level of assurance prior to operational use.

APPENDIX

This appendix is included for additional reference and contains a compilation of certain problems that have complicated the operation and maintenance activities at KSC.

A.1 CIVIL

A.1.1 Sewage. When buildings, sewage plants, and lift stations are designed or existing facilities altered, special attention should be paid to the following:

a. The size of restroom facilities should allow for expansion. Outdoor restroom facilities (for personnel in outlying areas) should comply with the latest Public Health, State, and Federal regulations.

b. Restroom ventilation air-handling units must be of adequate size, vibration-free, and reliable.

c. Equipment room soundproofing should be adequate to prevent unnecessary disturbance to personnel in adjacent areas.

d. Supplies and janitorial equipment storage areas must be adequately provided.

e. Sewage treatment plants and lift stations should be constructed of concrete (rather than steel) to eliminate corrosion.

f. Septic tanks should be designed according to location, natural conditions, and population. Tc avoid pollution problems, the leeching field should be percolation-tested to ensure proper drainoff, and soil pipe cleanoffs should be ground level and surrounded with a concrete pad. Septic tank covers of sufficient strength should be provided to allow vehicle traffic without breakage.

g. Gas chlorinator systems (for sewage treatment plants) require monthly refilling and should be selected over hypochlorinator systems (which require daily refilling).

h. Sewage treatment plant design shall provide the following:

(1) A flowmeter to provide accurate volume information (and conform to State and Federal pollution co trol laws).

(2) Scum removers (State requirement).

(3) Emergency bypass to pump out the system during an outage.

(4) All tanks with drains to facilitate maintenance.

(5) A positive sludge return design in lieu of an air lift return.

i. Cast iron pipe should be used, when feasible, for some types of sewers (asbestos-cement (Transite) pipe requires additional maintenance).

j. The following considerations should be given, when feasible, to sump pumps in order to reduce maintenance and costs:

(1) New manholes should have a sump pit on the bottom (to allow the use of a portable pump when maintenance on manhole is required).

(2) Sump pumps should be inexpensive (replaced rather than repaired upon failure).

k. The wet well/dry well type construction (sewage lift stations) has a longer life, is easier to maintain, and should be selected rather than the submerged pump design.

A.1.2 Air Conditioning. During air-conditioning design, special considerations must be given to the installation location and its accessibility for maintenance. Sufficient room must be provided to allow accessibility to the unit and its associated equipment. The following requirements should also be considered by the designer:

a. Serious consideration should be given to ceramic towers for new systems or tower replacement, to ensure a longer life and lower maintenance costs. (Wooden towers, with combined steel/wooden structural members, are often too costly and usually require complete disassembly for repair and corrosion treatment.)

b. Exposed (outside installations) air-conditioning equipment (air dampers, valve linkages, bearings, etc.) must be properly coated to prevent corrosion. The designer shall ensure that specifications state that there are proper protective coatings to exposed areas or that nonferrous materials are used by the contractor (upon installation in any new facility).

c. To reduce the extensive and rapid corrosion of exposed steel conduit and piping (in air-conditioning systems, water softeners, cooling towers, etc.) serious considerations should be given, where feasible in future projects, to properly coat or protect the exposed metallic surfaces or to use nonferrous materials.

d. Underfloor air-humidity control should be considered for all future installations of underfloor equipment rack air-conditioning systems to prevent equipment rack, console, and computer components corrosion.

e. A sufficient number of accessible balancing cocks should be provided, in air-conditioning piping systems, which encompass parallel equipment (chillers, condensers).

f. Conditioned air handiers must have traps installed in the condensate-drains (without a water seal, air can be pulled through the open end of the condensate line by the air handler, preventing drainage from the pan) to prevent continuous overflow conditions during warm weather.

g. The insulation thickness and type required should be based on the service and not on the lowest initial cost.

h. Condenser pump motors and outside operating gears should be equipped with reduced-voltage heating or with ample sized strip heaters.

i. The installation of RFI filters in air-conditioning ducts is not recommended. These installations restrict the airflow, and the internal console blower (in some applications) is incapable of pulling the sufficient airflow required. (This has required the installation of booster motors to meet air volume requirements.)

The abnormal natural environment (high humidity, wind-blown sand, driving rain) prevalent at KSC should be recognized, and the design should provide every reasonable protection from these conditions.

A.2 ELECTRICAL

Electrical repair and/or modification to systems usually requires complete outage to an entire facility and results in considerable cost to the Government. The designer should provide and consider the following:

a. All high-voltage lines should either be underground or overhead cable. (Open-wire electrical power lines are very susceptible to lightning at KSC.)

b. Where feasible, the use of PVC (polyvinyl-chloride) conduit should be used. (In many usages at this Center, PVC conduit has experienced a longer life usage.)

c. All electrical installation for new facilities should conform to the National Electrical Code. (Past installations with improper size feeder panels have resulted in expensive modifications.)

d. Printed circuit boards of a common type (e.g., flip-flops, emitter followers, etc.) shall be utilized in the design of equipment. The use of printed circuit boards of special design for a single application is too costly and generally undesirable.

e. Maximum use of fungi-inert materials should be utilized in preference to fungus protection, when feasible, in the design and for electrical applications. (Most fungus-resistant treatments, in the KSC environment, had a useful life of a few months.)

A.3 MECHANICAL

Special attention is required by designers to the following mechanical requirements:

a. Areas where sand and water can accumulate and be retained for extended periods of time should be eliminated. Drain holes should be provided in cabinets, trays, etc., that are not sealed, to allow water to drain out.

b. Airtight cabinets should be designed with adequate structural strength to withstand the effects of the exhaust of space vehicle engines, and/or adequate and reliable pressure relief should be provided. (Low pressures caused by rocket engine exhaust have often caused doors to buckle or be torn loose, in this induced environment condition.)

c. Nonpermanent vacuum type systems should be constructed for ease of maintenance, i.e., pump-down ports should not be through a "pinch-off" tube or a burst-disc port.

d. Careful attention is required to tolerance and design details where software seals are utilized to reduce possible physical damage, poor seating, misalignment, and distortion to t[illegible] seals.

e. Careful attention should be given to the design of sensing lines and tapped ports, i.e., instrument sensing lines and purge lines should not be combined.